

Systematic Review

Impact of Traffic Stress, Built Environment, and Socioecological Factors on Active Transport Among Young Adults

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Abstract

Active transport (AT) offers an effective and sustainable strategy to address physical inactivity, reduce traffic congestion, and mitigate environmental challenges. However, participation in AT among young adults (YA) aged 18–25 remains low, leading to public health issues. This review synthesises evidence on how traffic stress (TS), built environment (BE) features, and socioecological factors interact to shape AT behaviour among YA, a relationship that remains insufficiently understood. We systematically reviewed 173 peer-reviewed studies (2015–2025) from Web of Science (WoS), PubMed, and Scopus, following the PRISMA 2020 guidelines. Thematic analysis, bibliometric mapping, and meta-synthesis informed the impact of TS, the Level of Traffic Stress (LTS), the 5Ds of BE, and the Socioecological Model (SEM) on AT among YA. The findings show that high TS, characterised by unsafe road conditions, high-speed motor traffic, and inadequate walking or cycling facilities, consistently reduces AT participation. In contrast, supportive BE features, including street connectivity, land-use diversity, and destination accessibility, increase AT by reducing TS while enhancing safety and comfort. Socioecological factors, including self-efficacy, social norms, and peer support, further mediate these effects. This review introduces two novel metrics: Daily Traffic Stress (DTS), a time-sensitive measure of cumulative daily TS exposure, and the Stress-to-Step Ratio (SSR), a step-based index that standardises how stress exposures translate into AT behaviour. By integrating environmental and psychosocial domains, it offers a theoretical contribution as well as a practical foundation for targeted, multilevel policies to increase AT among YA and foster healthier, more equitable urban mobility.

Keywords: traffic stress; active transport; built environment; Socioecological Model; young adults; physical activity; daily traffic stress; stress-to-step ratio; literature review



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1. Introduction

Physical inactivity is a leading global public health challenge [1–3], contributing to an estimated 4–5 million preventable deaths annually [4]. Globally, approximately 31% of adults aged 18 years and older fail to meet the World Health Organization’s (WHO) physical activity (PA) recommendations [5]. PA is defined as any bodily movement produced by skeletal muscles that requires energy expenditure, encompassing activities in leisure, work, education, household, and transport domains [6]. AT is defined as a human-powered transportation mode such as walking or cycling [7,8], which makes a substantial contribution to overall PA levels [9–11]. AT is increasingly recognised as a distinct transport-related domain

of PA that can help to achieve recommended activity levels [10]. It is a cost-effective, accessible form of mobility that confers multiple health, social, and environmental benefits [12]. Despite these benefits, AT uptake remains limited, particularly among YA.

In Australia, only 22.4% of adults aged 18 to 64 achieve the national PA guidelines. Participation among females (19.9%) is lower compared to males (24.9%) [13]. In 2022 alone, a total of 1194 people lost their lives in road crashes across Australia, with 19% of these deaths occurring among those aged 17–25 years, a group that makes up only 11% of the national population [14], underscoring the urgency of improved mobility safety for YA. Improving perceptions of safety is critical, as safety concerns consistently rank among the most significant barriers to AT participation in global literature [15–17].

Accessible, sustainable forms of PA, such as AT, have been shown to reduce the risks of premature mortality [18], cardiovascular disease [19], cancer [20–22], and obesity [23]. The extant literature reports a 12% lower risk of breast cancer, a 30% lower risk of endometrial cancer [24], and reduced risks of obesity, hypertension, and diabetes with increased PA [25]. In Chile, data from the National Health Survey (2016–2017) showed that walkers and cyclists had lower odds of obesity compared to car travellers [26]. Together, these findings underline the broad health benefits of AT and its potential to reduce diseases throughout life.

Evidence suggests that walking as few as 7000 steps per day is associated with significant health benefits [27]. The WHO recommends that adults (aged 18–64 years) should engage in at least 150–300 min of moderate-intensity or 75 to 150 min of vigorous-intensity PA per week [6]. There is a dose–response relationship between PA and health status, indicating that an incremental increase in PA will incrementally improve health [28].

TS refers to the discomfort and perceived danger individuals experience when interacting with environments characterised by challenging road conditions, such as high traffic density, inadequate road design, and a lack of infrastructure for pedestrians and cyclists [29]. TS has been measured across studies using several tools, including the Bicycle Level of Service and Compatibility Index [30,31] and the most commonly used Level of Traffic Stress (LTS) [32,33]. The LTS framework categorises roads from LTS 1 (very low stress, suitable for children) to LTS 4 (high stress, suitable only for highly confident cyclists) [32,33] primarily based on infrastructure design features. Additionally, the Pedestrian Quality of Service framework [34] has been used to evaluate pedestrian experiences, although it does not directly categorise stress levels on a Likert scale.

Built environment (BE) features, particularly the 5Ds (Density, Diversity, Design, Destination, Distance), play a critical role in shaping AT engagement. The 5Ds capture key environmental factors that influence travel mode selection, route choice, and trip frequency [35,36]. Density, defined as the concentration of people or jobs in a given area, reduces travel distances and enhances service efficiency, thereby supporting AT participation [36–38]. Diversity, or mixed land use such as residential, retail, and institutional areas, enables access to multiple destinations through AT modes [36,39]. Design, including walkable street layouts, intersection density, and dedicated infrastructure, improves safety and AT usability [36,40]. Destination accessibility or easy access to everyday destinations like shops, parks, and schools increases AT likelihood [36,41]. Distance to transit matters because proximity to public transport encourages AT as part of multimodal trips [36,42].

The Socioecological Model (SEM) was introduced by McLeroy et al. in 1988 [43]. It provides a comprehensive framework for understanding how multiple levels of influence, ranging from individual to policy-level, interact to shape human behaviour. In the context of AT, SEM illustrates how personal, social, environmental, and institutional factors collectively influence the likelihood of walking or cycling [44]. At the individual level, determinants such as age, gender, physical ability, and personal attitudes directly shape

motivation to engage in AT [45]. The social environment, including cultural norms, peer influence, social cohesion, and perceived approval from others, can motivate or discourage AT participation [46,47]. The BE layer captures urban design, land use, and transport infrastructure that determine the safety, accessibility, and attractiveness of AT [48–50]. The natural environment, including factors such as climate and weather, also influences the feasibility and comfort of AT participation [51,52]. These layers interact dynamically, highlighting the need for integrated approaches to assess AT holistically.

Young adulthood is a critical transitional life stage, characterised by increased autonomy, identity development, and the formation of long-term behavioural and mobility habits, including independent transport decisions [53–57]. Promoting AT during this stage offers an opportunity to foster healthy lifelong behaviours and prevent the early onset of chronic diseases. Despite this potential, AT participation among YA remains low, indicating a pressing need for targeted synthesis to identify barriers, enablers, and actionable pathways. Existing measures of TS are largely static and do not account for temporal variability in exposure across daily travel periods. This presents a gap which is targeted in the current study. Accordingly, the proposed Daily Traffic Stress (DTS) extension addresses this limitation by integrating time-sensitive fluctuations in traffic, thereby providing a more realistic representation of AT challenges. Likewise, although step counts are widely employed as indicators of PA, they are rarely examined in conjunction with environmental and social stressors. The proposed Stress-to-Step Ratio (SSR) introduces a novel behavioural indicator that links exposure to TS with mobility outcomes, enabling a clearer evaluation of how stress translates into AT participation.

This study aims to answer the following question: “How do TS, BE features, and SEM factors collectively shape AT behaviour among YA?”. The following objectives are investigated to address the research question.

1. To synthesise existing evidence on how TS, BE features, and SEM factors interact to influence AT behaviours among YA.
2. To introduce DTS, a time-sensitive extension of LTS that captures daily traffic fluctuations.
3. To propose SSR, a step-based index linking stress exposures to changes in daily walking.
4. To integrate TS, LTS, the 5Ds of BE, and SEM within a unified framework, advancing a comprehensive conceptual understanding of AT behaviour in YA.

While TS, LTS, BE, and SEM each independently inform aspects of AT, their combined application has not been holistically assessed, especially in capturing the intersecting physical, psychological, and socio-contextual barriers that influence YA mobility choices. By synthesising multidisciplinary literature, this review provides a comprehensive understanding of how urban design, perceived stress, and social–ecological dynamics interact to shape AT behaviour among YA.

Figure 1 shows the integrated framework in which AT is positioned at the intersection of three interdependent domains: TS, the 5Ds of BE, and SEM. Infrastructure stressors, safety perceptions, and enabling environmental factors operate as mediating constructs, linking physical design, perceived risk, and social context. The framework highlights the multidimensional character of AT, demonstrating how structural, psychological, and socioecological determinants converge to shape mobility behaviours among YA.

Beyond integration, this study introduces two novel extensions: DTS and SSR. Together, these additions strengthen the integrated framework and provide a robust theoretical foundation for targeted interventions, innovative transport policy, and sustainable urban planning to promote AT among YA.

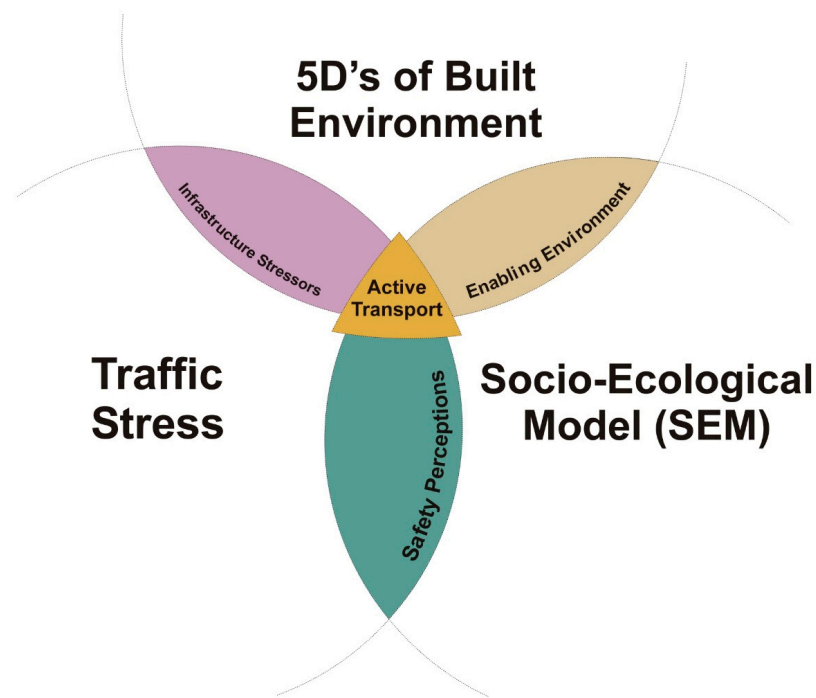


Figure 1. Integration of TS, the 5Ds of BE, and SEM to explain AT behaviour (diagram developed by the authors).

The rest of the paper is structured as follows. Section 2 presents the barriers and enablers of AT participation. Section 3 details the systematic review methodology, including the search strategy, study selection, quality assessment, and synthesis procedures. Section 4 presents the results and analysis, covering meta-synthesis, thematic findings, the DTS extension, and the development of SSR. Section 5 discusses the key findings in relation to TS, BE, and socioecological factors. Finally, Section 6 concludes the paper by summarising the main contributions, outlining policy and planning implications, and identifying directions for future research.

2. Barriers and Enablers of AT Participation

Barriers and enablers are determinants of whether YA adopt or reject AT as a regular travel choice. Barriers are environmental, infrastructural, or psychosocial constraints that discourage participation in AT. These include real or perceived safety risks, lack of infrastructure, and negative social or cultural norms [58,59]. Enablers are conditions that promote or support AT by improving safety, accessibility, and social acceptance, encompassing both BE features and supportive policies [37,60].

2.1. Barriers

Key barriers to AT participation include inadequate infrastructure, safety concerns, and a lack of supportive policies, which create physical and psychological impediments to walking or cycling [61,62]. Additional deterrents, such as TS, concerns about vehicle collisions, high-speed traffic, long distances between origins and destinations, absence of dedicated pathways, adverse weather conditions, limited surveillance (e.g., CCTV), land-use patterns, restrictive social norms, and household financial constraints, further discourage AT [63–65]. These barriers often intersect, compounding their impact. For example, a long commute may be made less feasible by high perceived TS. Poor lighting or unsafe crossings exacerbate feelings of vulnerability. Inadequate infrastructure is consistently associated with reduced AT uptake, as missing links in pedestrian and cycling networks, poor street connectivity, and the absence of physical separation from motor traffic elevate

both objective and perceived risk, pushing routes into higher LTS categories [33,37]. These infrastructural limitations are reinforced by safety concerns, where fast-moving vehicles, insufficient crossing facilities, and near-miss experiences heighten perceived danger, reduce behavioural control, and reinforce avoidance of walking and cycling [60,66]. Even when infrastructure is available, long travel distances hinder AT. Less land-use diversity amplifies this deterrent by restricting access to proximate destinations and everyday services [67,68]. Weather extremes, including heat, heavy rainfall, and strong winds, further undermine comfort and predictability, often overriding the potential benefits of supportive infrastructure [69]. Finally, unsupportive cultural norms, particularly concerns related to women's safety, weaken self-efficacy and social acceptance, discouraging participation in walkable and cycle-friendly settings [70,71]. Table 1 lists and explains the commonly reported barriers to AT participation.

Table 1. Common barriers to AT participation.

No	Common Barriers	Explanation	Classification (LTS, 5Ds, SEM)	Selected References
1	Inadequate walking and cycling infrastructure	Lack of connected footpaths, protected lanes, or crossings discourages AT.	LTS, 5Ds	[33,37]
2	Perceived TS and safety concerns	Fear of fast motor vehicles, lack of separate lanes from traffic, or prior negative experiences.	LTS, SEM	[60,66]
3	Long distances between the origin and the destination	Extended travel distances reduce the feasibility of walking/cycling for daily commutes.	5Ds, SEM	[67,68]
4	Adverse weather conditions	Unfavourable climate (e.g., heat, rain) makes AT uncomfortable.	SEM	[69]
5	Negative social or cultural norms	Social attitudes may discourage AT, especially for women or marginalised groups.	SEM	[70,71]
6	Physiological stress during traffic exposure	Exposure to noise, pollution, and stress responses reduces willingness to walk/cycle (AT).	LTS	[29]
7	Air pollution during commuting	Pollution exposure deters walking and cycling for health reasons.	SEM, BE	[72]
8	Policy inaction	Weak prioritisation of AT in planning and investment constrains uptake.	SEM	[73,74]
9	Lack of social support	Limited encouragement from peers reduces motivation for PA(AT).	SEM	[47]
10	Weak enforcement of safety policies	Inadequate regulation or policy enforcement increases cycling risks.	SEM, LTS	[75]

2.2. Enablers

Enablers such as well-designed urban spaces (BE), community engagement, and strong policy frameworks can transform cities into hubs of AT mobility [63]. Well-designed and connected infrastructure reduces exposure to traffic, reduces travel time, and lowers LTS. For example, when footpaths and cycleways are continuous, AT participation increases [37,67,76]. If roads are calmed and bike lanes are physically protected, then perceived and actual crash risks decline, enabling AT participation among broader groups [33,66]. Supportive policies and urban planning embed AT into land-use design and

funding priorities. When these considerations are present, population-level walking and cycling prevalence is consistently greater [60,68]. Community engagement and awareness programs normalise AT and strengthen self-efficacy. When social acceptance grows, individual adoption follows [37,60]. Access to green space and mixed land use optimises trip distances and enhances environmental quality and visual appeal. When such conditions are present, AT becomes both feasible and attractive [77,78]. Table 2 lists the commonly reported enablers to AT participation.

Table 2. Common enablers of AT participation.

No	Common Enablers	Explanation	Classification (LTS, 5Ds, SEM)	Selected References
1	Well-designed and connected infrastructure	Continuous sidewalks, bike paths, and crossings improve AT usability.	LTS, 5Ds	[37,67]
2	Traffic calming and protected bike lanes	Lower traffic speed and physically separated lanes improve safety.	LTS	[33,66]
3	Supportive policies and urban planning	Integrated planning supports walkability and health goals.	5Ds, SEM	[60,68]
4	Community engagement and awareness	Awareness campaigns and peer support improve AT acceptance.	SEM	[37,60]
5	Green space access and mixed land use	Walkable access to destinations supports daily AT.	5Ds	[77,78]
6	Peer and social influence	Peer effects and workplace norms encourage active commuting	SEM	[47]
7	Residential preference for walkable neighbourhoods	Individuals who choose walkable areas engage more in AT.	5Ds	[79]
8	All-ages-and-abilities infrastructure	Inclusive cycling design supports uptake across age groups	5Ds, LTS	[80]
9	Positive cycling experiences	Enjoyment, relaxation, and subjective satisfaction encourage continued AT.	SEM	[81]
10	Perceived safety for young users	Parents and children are more likely to choose AT when safety is assured.	LTS	[62]

This study systematically explores the above barriers and enablers through four interrelated frameworks: TS, LTS (including LTS 1, LTS 2, LTS 3, and LTS 4), the 5Ds of BE, and SEM. These frameworks provide a comprehensive structure for understanding how environmental and social determinants jointly influence AT behaviours among YA.

3. Methodology

The study followed a structured multi-step approach, as illustrated in Figure 2. In the first step, literature was retrieved from Scopus, Web of Science (WoS), and PubMed. These databases are widely recognised as core sources in interdisciplinary systematic reviews [82,83]. This combination offers both breadth and efficiency, ensuring comprehensive coverage of peer-reviewed journal articles. Search strings were finalised and restricted to studies published between 2015 and 2025 on AT, TS, BE, SEM factors, and YA. In the

second step, articles were screened, shortlisted, and grouped by themes. Bibliometric and Google Trends analyses were conducted to complement the evidence base and capture broader research and public attention. In the final step, articles were synthesised thematically. New extensions of LTS were introduced, including the DTS framework and SSR, before consolidating the findings through discussion, conclusions, and recommendations.

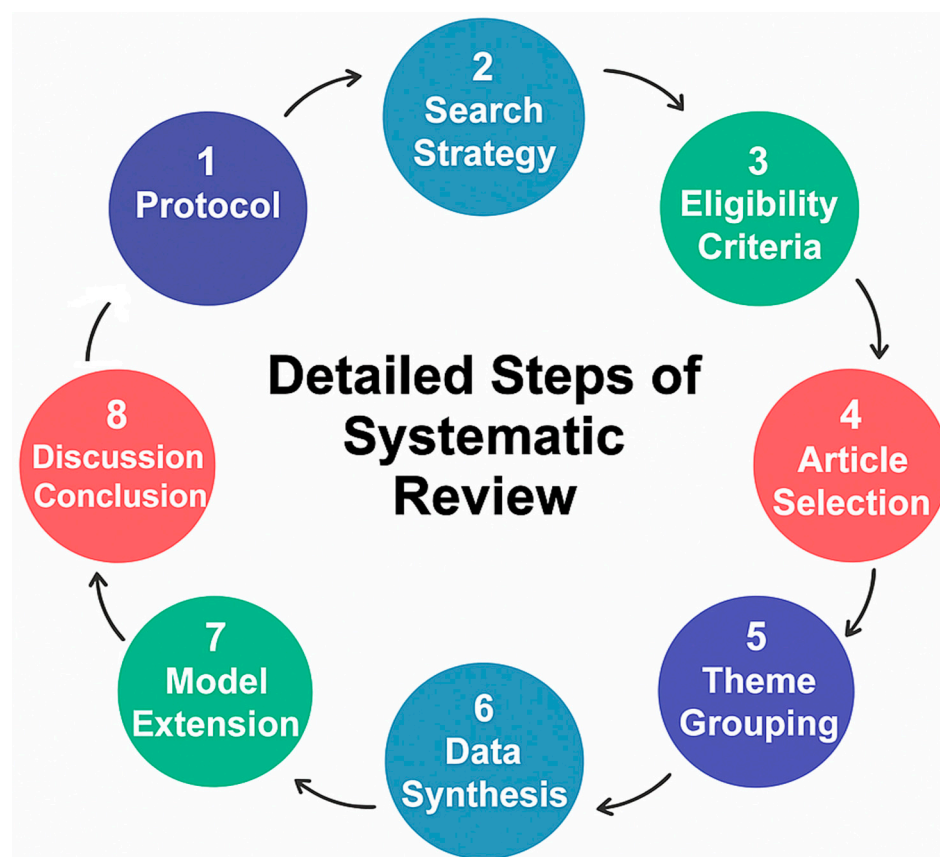


Figure 2. Methodological workflow of the systematic review (diagram developed by the authors).

3.1. Systematic Review Framework and Process

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [84] (Supplementary Materials). It applies a structured protocol to ensure transparency and methodological rigour. Figure 3 presents the PRISMA diagram for the current study. A detailed protocol was developed to guide database selection, screening criteria, and synthesis of findings. The primary population focus is YA. Studies examining relevant constructs such as TS, LTS, BE, or SEM influences involving adjacent age groups were also included. This aligns with the transferable nature of frameworks such as LTS, walkability indices, and land-use diversity, which are not strictly age-specific but applicable across demographic ranges.

There is no international consensus on age boundaries for YA [85]. The WHO defines adolescence as the age between 10 and 19 years old [86], while the United Nations defines youth as 15–24 years old [87]. In the United States, federal health agencies such as the Substance Abuse and Mental Health Services Administration (SAMHSA) classify individuals aged 18–25 years as YA [88]. In Australia, individuals aged 18–24 are recognised as YA [89]. Due to variability in definitions across studies and jurisdictions, limiting inclusion strictly to 18–25 could exclude valuable insights. Therefore, studies with broader populations having findings transferable to mobility patterns were retained when they addressed BE features conceptualised through the 5Ds, TS, LTS, and SEM in relation to AT.

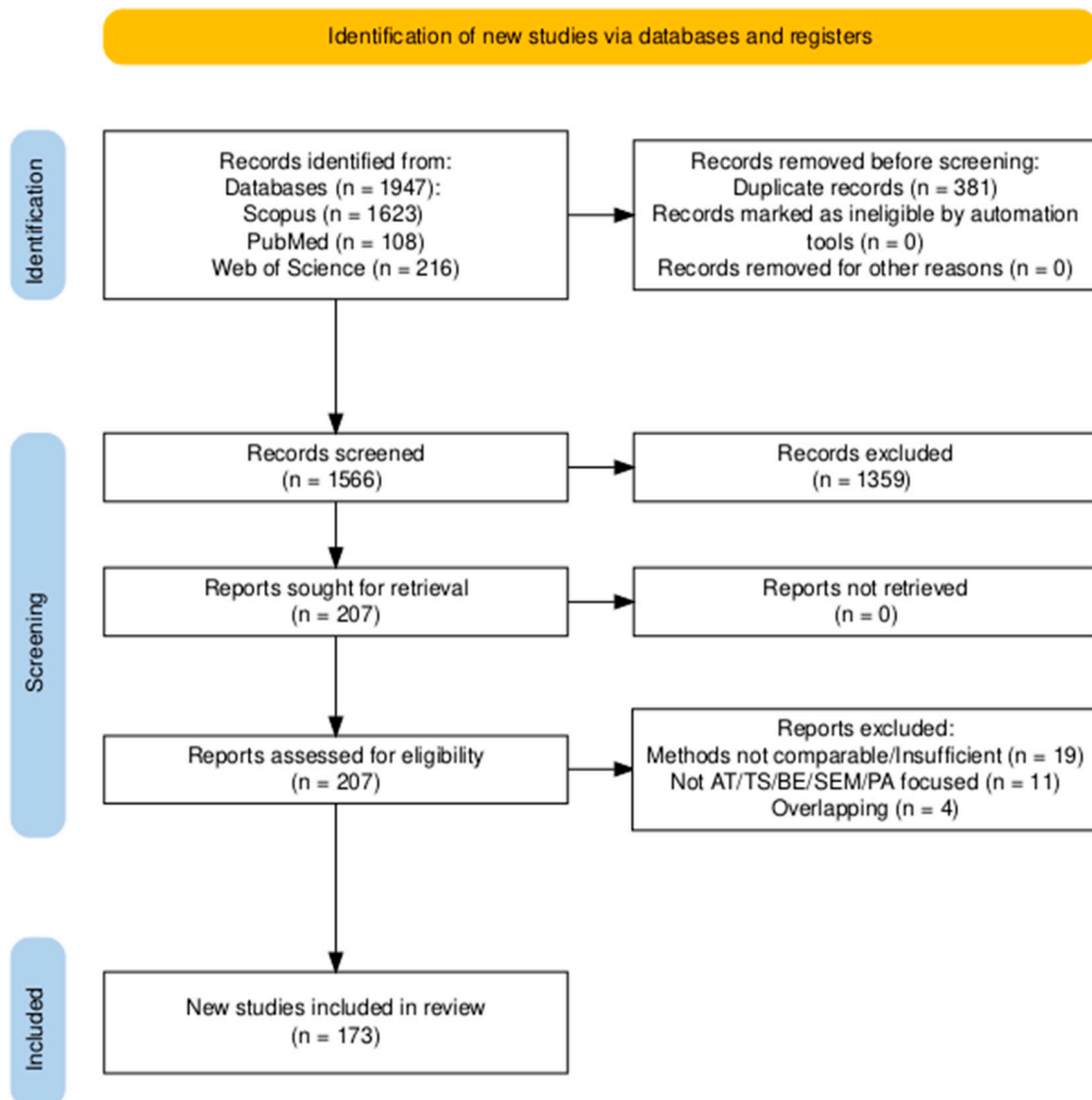


Figure 3. PRISMA flow diagram summarising the study selection process.

The systematic review process was conducted in accordance with PRISMA 2020 [84]. It comprised sequential stages of protocol design, eligibility specification, database searching, study selection, data extraction, quality appraisal, and evidence synthesis (Figure 3). A protocol was developed a priori but was not formally registered in any public database. Searches were conducted in Scopus, PubMed, and WoS using strings based on Boolean operators (Table 3). Retrieved records were imported into EndNote, duplicates were removed, and studies were screened in two stages: title/abstract and full-text review. Data were extracted using a structured form capturing author(s), year, design, geography, sample characteristics (including age groups), PA and AT outcomes, TS/LTS measures, BE (5Ds), SEM constructs, and key findings. Methodological quality was assessed using the Joanna Briggs Institute (JBI) appraisal tools [90], evaluating sampling adequacy, study design, validity of measures, management of confounding, attrition, and reporting quality. However, no study was excluded solely on the basis of quality. Evidence was synthesised through bibliometric mapping in VOSviewer (keywords, co-authorship, citation analysis). Thematic synthesis was structured around TS, LTS, BE, and SEM. Potential publication bias was

mitigated through multi-database searching, consistent eligibility rules, and transparent documentation of exclusions.

Table 3. Search strings and records retrieved.

Database	Search String Used	Years Covered	Filters Applied	Count
Scopus	((“traffic stress” OR “active transport” OR “active travel” OR (“physical activity” AND (transport OR commuting OR mobility)) OR “built environment” OR “socioecological model”) AND (“young adults”))	2015–2025	English, peer-reviewed journal articles only	1623
PubMed	((“traffic stress” [Title/Abstract] OR “active transport” [Title/Abstract] OR “active travel” [Title/Abstract] OR (“physical activity” [Title/Abstract] AND (transport [Title/Abstract] OR commuting [Title/Abstract] OR mobility [Title/Abstract])) OR “built environment” [Title/Abstract] OR “socioecological model” [Title/Abstract]) AND (“young adults” [Title/Abstract]))	2015–2025	English, peer-reviewed journal articles only	108
Web of Science	((“traffic stress” OR “active transport” OR “active travel” OR “physical activity” OR “built environment” OR “socioecological model”) AND (“young adults”) AND (transport OR commuting OR mobility))	2015–2025	English, peer-reviewed journal articles only	216
Subtotal				1947
Irrelevant records excluded	Biomedical, clinical, and unrelated stress/transport articles identified through title and abstract screening, removal of duplicates, and methodological quality appraisal			1774
Final records included	Studies conceptually aligned with TS, AT, BE, SEM, PA, and YA			173

3.2. Search Strategy, Databases, and Eligibility Criteria

A comprehensive, theory-informed search strategy was developed to identify peer-reviewed studies examining the relationship between TS, AT, BE, SEM, PA, and YA. Searches were conducted across three major databases—Scopus, PubMed, and WoS—due to their multidisciplinary coverage and relevance to the topic. The search was limited to peer-reviewed journal articles published between 2015 and 2025 to ensure inclusion of high-quality, credible evidence, as peer review remains the cornerstone of scientific validation and methodological transparency in academic publishing [91]. Table 3 lists the search strings used in this study.

Across the three repositories, a total of 1947 records were retrieved. After removal of duplicates (number of papers (n) = 381), 1566 unique records were screened by title and abstract. Of these, 1359 were excluded for not meeting inclusion criteria (e.g., wrong population, not related to AT/TS/BE/SEM, PA clinical or non-human studies). The remaining 207 full texts were assessed for eligibility, of which 173 studies met all criteria and were included in the final synthesis. The PRISMA 2020 flow diagram (Figure 3) summarises this process.

Eligibility criteria were applied to ensure the review remained focused on high-quality and conceptually relevant evidence. The inclusion rules targeted peer-reviewed journal articles addressing AT, TS, BE, LTS, PA (transport domain), SEM, and YA, while exclusion rules

removed studies outside this scope. Table 4 summarises the detailed inclusion and exclusion criteria adopted in this review, developed in accordance with the PRISMA guidelines.

Table 4. The inclusion and exclusion criteria.

Inclusion Criteria	Exclusion Criteria
Peer-reviewed journal articles (2015–2025)	Non-peer-reviewed publications and those published before 2015
Studies examining AT, TS, BE, LTS, YA, PA (transport domain), and/or SEM	Studies not addressing AT, TS, BE, LTS, YA, PA (transport domain), or SEM
Articles investigating TS in relation to AT participation, or examining BE, SEM, or LTS determinants of AT	Studies unrelated to AT or TS (e.g., animal studies, cellular transport, psychological stress not linked to mobility)
Studies addressing urbanisation or socioecological determinants of AT	Studies limited to clinical or laboratory-based interventions without AT relevance
Research involving YA (18–25), or broader age groups if conceptually relevant to AT, TS, BE, PA (transport domain), or SEM	Research not involving YA or broader age groups relevant to AT, TS, BE, PA (transport domain), or SEM
English-language articles	Non-English articles
Published journal articles	Grey literature (e.g., reports, working papers), conference proceedings, and book chapters often lack rigorous peer review and consistent methodological detail

The review’s evidence base was restricted to studies from 2015 onwards, with a few earlier core studies and Queensland Government transport reports included to inform contextual patterns and the DTS extension. These sources were excluded from PRISMA totals but were essential for model development.

3.3. Study Selection, Data Extraction, and Quality Assessment

Study selection followed the PRISMA 2020 guidelines [84] to ensure methodological rigour and transparency. After removing duplicates, all authors independently screened titles and abstracts against the predefined eligibility criteria (Table 4). Full-text articles of potentially relevant studies were then assessed. Any discrepancies during screening were resolved through discussion until a consensus was reached.

Data were extracted using a structured, PRISMA-informed sheet, capturing the following variables: author(s), publication year, study design, country/region, sample characteristics (age range, size), instruments used for AT, TS, BE, SEM, PA, and key findings relevant to the review objectives.

Data extraction was conducted by the lead author and cross-verified by the second author. Methodological quality and risk of bias were assessed using the JBI critical appraisal checklist for qualitative studies [90]. Evaluation criteria included sampling and selection bias, appropriateness of study design, management of confounding factors, validity of measurement instruments, participant attrition and follow-up, analytical rigour, and reporting quality. Each study was assigned an overall quality score on a 0–10 scale based on the JBI checklist, with higher scores indicating stronger methodological rigour. For interpretation, scores of 0–4 were considered low quality, 5–7 moderate quality, and 8–10 high quality. However, no study was excluded solely based on quality to avoid any authors’ bias.

3.4. Meta-Analysis and Thematic Analysis

A structured meta-synthesis was undertaken, incorporating Google Trends analysis, bibliometric mapping, and thematic analysis to integrate findings across heterogeneous

study designs. Quantitative studies were investigated to extract interpretable results, including reported associations, contextual explanations, and authors' interpretations [92,93]. This approach enabled alignment with qualitative and mixed-methods approaches. Instead of statistical pooling, a meta-summary method was applied [94], allowing identification of recurrent patterns in how TS, BE, and SEM factors influence AT among YA. The authors conducted the synthesis independently, resolving discrepancies through consensus to enhance rigour and reproducibility.

A thematic analysis was performed following Braun and Clarke's six-phase framework [95]. Deductive coding was applied to constructs from LTS, the 5Ds, and SEM, while inductive coding captured emergent insights such as youth-specific psychosocial barriers. Coding was conducted in NVivo 14 [96,97]. This process enabled the integration of both a priori theoretical constructs and emergent themes, strengthening the validity of the synthesis [98].

3.5. Time-Sensitive Extension of the LTS Framework

To address the static limitations of conventional LTS classifications [32,33], a time-sensitive extension was developed using 2023 Queensland TMR traffic data [99]. Hourly weekday and weekend traffic volumes were integrated into existing LTS thresholds to create four temporal categories: morning peak, midday, evening peak, and off-peak. This framework, termed DTS, reflects temporal variability in traffic exposure and provides a more sensitive measure of YA mobility experiences. By extending LTS from a static to a temporally responsive framework, DTS enhances its methodological utility and strengthens its policy and planning relevance for designing AT infrastructure.

3.6. Stress-to-Step Ratio

3.6.1. Benchmark Justification for Stress-to-Step Ratio

Zhao et al. [100] analysed 479,856 US adults (aged 18 years or older) and found that individuals who met the 2018 US PA guidelines [101] had significantly lower risks of all-cause and cause-specific mortality, compared to those who did not meet the guidelines. The analyses included deaths from cardiovascular disease, cancer, and chronic lower respiratory tract diseases. These individuals engaged in at least 150 min per week of moderate-intensity aerobic activity and muscle-strengthening exercise. Similarly, Martinez-Gomez et al. [102] examined seventeen annual US samples from 1998 to 2014 ($n = 482,756$) [101]. The authors highlighted that adults achieving at least 150 min per week of aerobic activity plus two or more muscle-strengthening sessions had their mortality risk reduced by 5 years. Both the US [101] and WHO [6] PA guidelines prescribe the same minimum threshold of 150 min per week of moderate-intensity activity, providing a consistent global benchmark for public health research. This globally harmonised standard was therefore adopted in this study to ensure international comparability and methodological consistency. The 150-min guideline for adults aged 18 years and older is consistent across body size or weight but does not account for environmental barriers, which can limit its applicability to specific cases. The proposed SSR extends this benchmark by linking PA duration with stress exposure, providing a context-sensitive indicator of daily activity.

3.6.2. SSR Formulation and Validation

SSR is a novel step-based metric introduced in this study that integrates BE features, environmental exposures (e.g., TS, safety, weather), and socioecological factors (e.g., perceptions, norms, self-efficacy) into a single interpretable indicator of walking participation. By expressing daily step gains or losses per unit of stress exposure time, SSR provides a practi-

cal measure of how multidimensional determinants collectively influence PA. Equation (1) is used to calculate the SSR value.

$$\text{SSR} = \frac{\text{Steps}}{\text{Traffic Stress Minutes (TSM)} + \varepsilon} \quad (1)$$

where Steps = daily gain or deficit (steps/day); TSM = minutes of exposure to low- or high-stress conditions; and $\varepsilon = 0.1$ to prevent division by zero.

Exposure times are rarely reported in primary studies, so TSM was benchmarked at 30 min/day. This value was derived from WHO recommendations (150–300 $\frac{\text{min}}{\text{week}}$ of moderate-intensity PA [6] equivalent to 21–43 $\frac{\text{min}}{\text{day}}$), with a midpoint (d_{mid}) of 32.1 min rounded to 30 as shown in Equations (2) and (3). In the equations, d_{min} and d_{max} refer to the minimum and maximum durations, respectively.

$$d_{\text{min}} = \frac{150}{7} = 21.4 \frac{\text{min}}{\text{day}}, d_{\text{max}} = \frac{300}{7} = 42.9 \frac{\text{min}}{\text{day}} \quad (2)$$

$$d_{\text{mid}} = \frac{d_{\text{min}} + d_{\text{max}}}{2} = \frac{21.4 + 42.9}{2} = 32.1 \frac{\text{min}}{\text{day}} \quad (3)$$

Tudor-Locke et al. [103] was used for validation, who demonstrated that cadence is strongly linked to walking intensity. A threshold of $\geq 100 \frac{\text{steps}}{\text{min}}$ is recognised as moderate-intensity walking (3 metabolic equivalents (METs)). Although mean daily cadences are low ($7.7 \frac{\text{steps}}{\text{min}}$) because much of the day is spent inactive ($< 60 \frac{\text{steps}}{\text{min}}$), reported peak values in healthy adults exceed $100 \frac{\text{steps}}{\text{min}}$ for 1 min and $70 \frac{\text{steps}}{\text{min}}$ for 30 min. Using the $100 \frac{\text{steps}}{\text{min}}$ threshold, 30 $\frac{\text{min}}{\text{day}}$ corresponds to 3000 steps, providing a clear translation of TSM into both per-minute exposure and total daily steps.

Additional behavioural evidence reinforces the validity of the 30 min benchmark. For example, Hajna et al. [104] reported one of the lowest positive gains of $+606 \frac{\text{steps}}{\text{day}}$ in high- versus low-walkability neighbourhoods. Dygryn et al. [105] reported a variation of $+2088 \frac{\text{steps}}{\text{day}}$. These gains correspond to approximately 6–20 min of moderate walking. Conversely, rainfall was shown to reduce daily steps by about 830 (570–1080) among individuals averaging 10,000 $\frac{\text{steps}}{\text{day}}$ [106]. High temperatures were linked to decreases of 800–1500 steps compared with moderate temperatures [107], equating to 8–15 min of reduced walking. Together, these observed ranges align closely with the 30 min exposure window, reinforcing their appropriateness as a standard benchmark for SSR calculations. By linking stress exposure directly to step-based outcomes, SSR offers a novel, interpretable indicator of how BE, environmental, and socioecological stressors translate into measurable impacts on walking behaviour.

4. Results and Analysis

4.1. Google Trends and Bibliometric Analyses

Google Trends and bibliometric analyses were conducted in this study. Google Trends analyses examined search interest in keywords relevant to this study (Figure 4a–c). Five terms were used—AT, TS + traffic safety, BE, YA, and peer influence + family support—displayed for 2015–2025 across web, image, and news searches. Web searches showed the highest visibility for socioecological and demographic terms, while AT displayed only intermittent peaks. BE and TS + traffic safety had the lowest activity, confirming limited public focus despite their research significance. Image searches showed minimal activity with only occasional spikes. The socioecological and infrastructure terms were underrepresented. News searches demonstrated negligible activity, with only two short spikes for peer influence + family support and almost no coverage of the other terms.



Figure 4. Google Trends results (Australia, 2015–2025) for the terms active transport, traffic stress + traffic safety, built environment, young adults, and peer influence + family support. Values represent relative search interest (0–100), with higher values indicating greater visibility of the term.

Taken together, these results highlight a disconnect between public and media focus and the evidence base. BE, TS, and socioecological factors remain underrepresented in public search behaviour and news coverage, despite being critical drivers of AT among YA. The disconnect between public interest and academic research priorities, evident in Figure 4, reflects what Kuhn [108] argued in their book *“The Structure of Scientific Revolutions”*. The authors argued that paradigm shifts in science take time to be accepted and translated into broader societal understanding. This also aligns with the words of Nobel laureate

economist Angus Deaton (1945 to date), who highlighted a common issue of academic researchers wandering off on a narrower research trail, which is intellectually exciting to them but of minimal interest to others [109]. Based on these, it can be inferred that people's perceptions follow research. In the context of AT, this gap implies that policymaking and public health communication must not only disseminate research findings more effectively but also invest in public education to raise awareness of how the built environment and traffic stress shape health behaviours.

The bibliometric analysis was conducted to complement the synthesis by mapping research domains. Keyword co-occurrence data were extracted from the three repositories (Figure 5a–c), standardised through cleaning (e.g., merging synonyms and converting plurals to singular forms), and analysed using VOSviewer (v.1.6.19). A minimum occurrence threshold of five keywords was applied. Four clusters consistently emerged: (1) BE (land use, walkability, urban design); (2) health outcomes (obesity, body mass, PA); (3) population and psychosocial factors (YA, health behaviours, psychology); (4) mobility behaviours (AT, walking, cycling, travel behaviour).

The WoS articles emphasised BE–PA links, while Scopus highlighted YA, BE, psychology, health, and biomedical determinants. PubMed reflected an age- and health-centric focus on YA, BE, and health promotion. Collectively, these domains illustrate the intersection of environmental, health, and psychosocial determinants, with YA consistently being central. This bibliometric mapping provided not only descriptive insights but also a reproducible evidence base to guide thematic synthesis and highlight underexplored research gaps.

The synthesis incorporated peer-reviewed studies that employed diverse methodologies to investigate the influence of TS, BE attributes, and SEM factors on PA and AT behaviours in YA. Cross-sectional surveys were the most common design, often using validated instruments such as the International PA Questionnaire and the Global PA Questionnaire [110–112] to measure PA and transport behaviours. Systematic and scoping reviews synthesised evidence on TS, BE, PA, and AT [113–115], while natural experiments evaluated behavioural responses to infrastructural or policy changes [80,116].

Geographic Information System (GIS) and spatial analyses were used to assess walkability, route connectivity, and environmental safety, whereas retrospective analyses of national datasets linked travel behaviours to public health outcomes [117–119]. Quantitative studies estimated associations between BE indicators and AT participation [38,120]. Qualitative and mixed-methods studies explored perceived safety, mobility barriers, emotional responses to traffic exposure, and lived experiences of AT users [121,122]. Policy reviews examined regulatory frameworks, infrastructure investment patterns, and institutional support mechanisms relevant to AT in YA [123,124].

Across designs, the synthesis consistently demonstrates how environmental stressors and BE interact with social norms, safety perceptions, and behavioural identity constructs within SEM. Collectively, these findings indicate that AT engagement among YA is shaped by physical infrastructure and traffic exposure as well as by interpersonal influences, community norms, and broader policy environments. This diverse, multi-method evidence base provides a foundation for thematic analysis. It informs the development of an integrated framework that captures the physical, psychological, and socio-contextual dimensions of AT behaviour in YA.

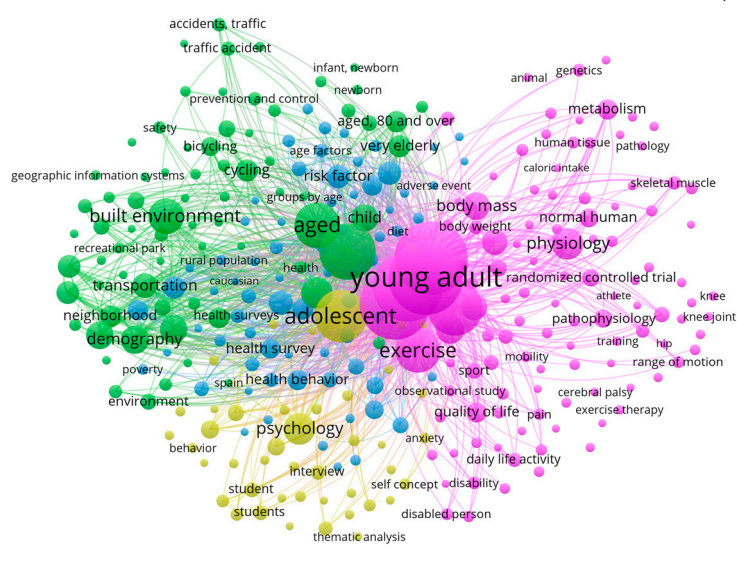
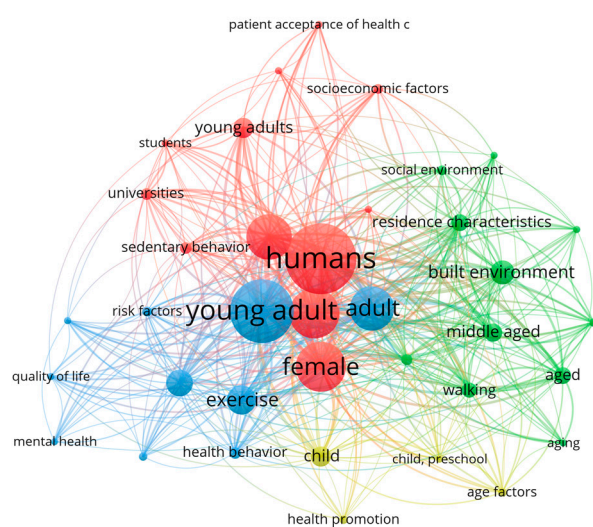
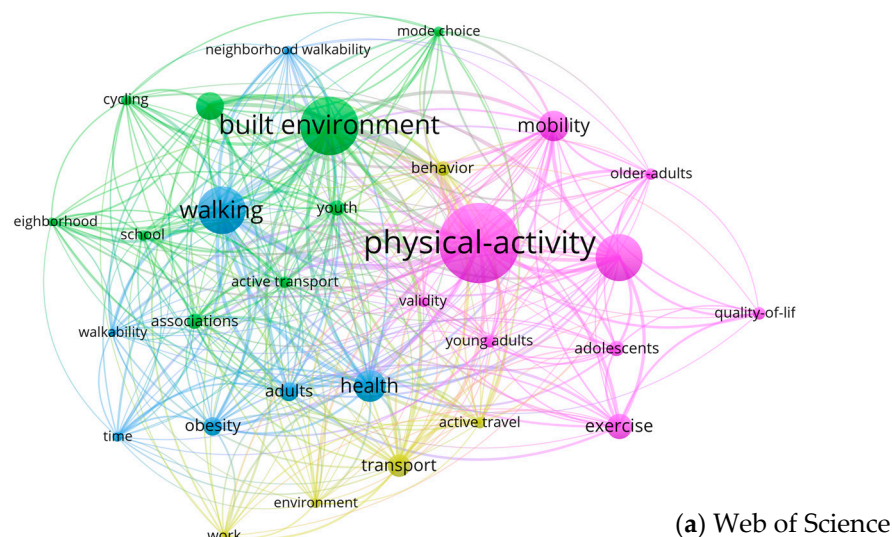


Figure 5. VOSviewer clustering of the retrieved papers: (a) Web of Science, (b) PubMed, (c) Scopus.

4.2. Thematic Analysis

A thematic analysis was conducted to synthesise and structure the diverse findings of the included studies. Thematic categories were derived through a combination of natural clustering and theory-informed grouping, based on recurring concepts and relationships observed during full-text data extraction and review. This approach ensured both inductive insights from the data and deductive alignment with established constructs such as SEM, BE frameworks, TS and LTS classifications, and broader transport, BE, and public health literature.

The initial coding involved annotating key variables, outcomes, and contextual features across studies. These codes were then iteratively grouped into higher-order themes using a reflexive process supported by literature on urban mobility, psychosocial stress, and YA behaviour. Discrepancies in thematic classification were resolved through team discussions and cross-checking with pre-identified theoretical constructs. This process yielded five core themes listed below and subsequently discussed:

- BE determinants comprising physical infrastructure, land-use mix, walkability, spatial connectivity, and urban form.
- TS and SEM determinants comprising perceived safety, emotional stressors, and behavioural avoidance in high-traffic settings.
- Policy and planning gaps comprising inconsistencies in AT infrastructure prioritisation, investment, and governance.
- YA behaviour and lifestyle contexts comprising age-specific perceptions, life-stage transitions, routines, and socio-cultural influences on AT choices.
- Mixed and overlapping themes comprising integrated or cross-domain studies that span multiple categories or reflect intersectional dynamics.

These themes provide a structured understanding of how urban stressors, spatial design, and socioecological influences interact to shape AT behaviours in YA.

4.2.1. Built Environment Determinants

BE is a primary determinant of AT participation [125,126]. Key urban features such as land-use mix, intersection density, walkability, and proximity to destinations are consistently associated with higher AT participation [127,128]. Access to educational institutions, recreational spaces, public transport, and retail areas further increases AT engagement [129–131].

Green infrastructure, including tree-lined streets, public parks, and shaded footpaths, improves thermal comfort, visual quality, and public space usability, enhancing the appeal of AT, particularly in warmer climates [132–134]. Well-maintained pavements, protected bike lanes, adequate lighting, and safe crossings contribute to perceived safety and travel satisfaction, while damaged walkways, poor signage, and motor-traffic dominance act as deterrents [135–137].

Integration of connected AT networks with public transport strengthens multimodal commuting potential. Cities without such integration report lower AT participation [138,139]. Pedestrian-oriented planning and spatial connectivity are central to embedding AT within urban design [37,39,140]. These findings highlight that BE features supporting accessibility, safety, and connectivity provide the essential foundation for sustained AT engagement in YA.

BE factors such as land-use diversity, connectivity, and infrastructure quality consistently enhance AT participation among YA by improving accessibility, safety, and convenience. Conversely, poorly designed or disconnected environments restrict opportunities and reinforce reliance on motorised transport. Table 5 lists the key BE factors and their impact on AT in YA.

Table 5. BE factors and their impact on AT in YA.

S. No.	Factor	Study Context	Study Focus	Impact on AT	Ref.
1	Accessibility and safety barriers	Adults with long-term physical disabilities	Explored how adults with disabilities perceive BE factors (safety, transport, accessibility, community).	Unsafe, inaccessible environments restricted participation.	[125]
2	Policy and BE interventions	Systematic review of 37 studies	Reviewed natural/quasi-experiments on policy and BE changes affecting PA and AT.	AT infrastructure improvements showed stronger impacts.	[126]
3	Health-integrated urban planning	Case study	Developed methods linking PA outcomes to mode share and vehicle kilometres travelled.	Incorporating AT into urban planning improved health integration.	[127]
4	Green infrastructure (eye-level greenery)	China (811 students, 10 universities)	Analysed street-view greenery and PA using regression models.	Visible greenery correlated positively with PA and walking (AT).	[132]
5	Cycling infrastructure preferences	Systematic review of 54 studies	Reviewed preferences for cycle infrastructure by gender and age.	Women and older adults preferred cycling infrastructure separated from roads.	[136]
6	Bicycle–train integration	Netherlands (54 train stations)	Modelled bicycle–train integration policy scenarios.	Better routes and parking increased ridership and AT integration.	[138]
7	Integrated city planning	Global scope	Identified planning interventions promoting walking, cycling, and public transport.	Compact, connected planning supported AT and reduced car use.	[37]

4.2.2. TS and SEM Determinants

Beyond physical infrastructure, psychological perceptions of TS significantly influence AT behaviours [141]. Perceived safety, emotional stress, and comfort are key determinants of transport mode choices [17,81,142]. Discomfort while walking or cycling is heightened in areas with high traffic volumes, speeding vehicles, or inadequate pedestrian infrastructure [143,144].

Fear of accidents, particularly in car-dominated or mixed-use environments, is a key deterrent to AT in YA [145]. AT users frequently express anxiety about being struck by motor vehicles, navigating complex intersections, and the lack of physical separation between motorised and non-motorised modes [145,146]. These anxieties are intensified in areas with poor visibility, high noise levels, and limited pedestrian signalling [146–148].

Personal safety concerns are especially prominent among female participants [149] and those commuting during late hours [150]. Isolated pathways, with insufficient lighting, generate emotional discomfort and prompt route avoidance, even when infrastructure quality is adequate [150,151]. Conversely, low TS environments, visible green elements, and clear separate lanes for transport modes are associated with greater satisfaction, reduced anxiety, and positive AT experiences [141]. Such settings promote feelings of relaxation, clarity, and mental restoration during travel among YA [141,152].

Cultural norms, self-identity, and social support also influence AT engagement in YA [153,154]. Individuals with low self-confidence, limited social support, and car-oriented norms often participate less in AT, even in supportive environments [155,156]. Sustained AT

participation, therefore, depends not only on infrastructure quality but also on emotional well-being, autonomy, and community-level support systems [157,158].

TS and SEM factors strongly influence YA decisions to engage in AT. High traffic volumes, safety concerns, and emotional stress discourage participation, while supportive social norms, low TS routes, and positive perceptions increase confidence and sustained engagement. Table 6 lists the key TS and SEM determinants and their impact on AT in YA.

Table 6. TS and SEM determinants and their impact on AT in YA.

S. No.	Factors	Study Context	Study Focus	Impact on AT	Ref.
1	Safety and comfort perceptions	Australian adults aged 18–80 (N = 1737)	Established normative scores of affects (safety, comfort, valence, arousal) using a video-based survey of cycling environments	Physically separated cycling facilities, such as off-street shared-use paths and protected bike lanes, were perceived as the safest and most comfortable, encouraging greater cycling participation	[141]
2	Perceived safety, security, comfort	Systematic review (68 studies, last 10 years)	Reviewed determinants affecting pedestrians' and cyclists' perceptions of safety, security, and comfort	Fear of traffic-related injuries, poor infrastructure, pollution, poor lighting, and crime negatively influenced AT perceptions	[17]
3	Travel satisfaction	Ghent, Belgium (cross-sectional data)	Analysed the cyclical process between travel satisfaction and future active mode choice	Satisfactory walking and cycling trips improved attitudes, increasing the likelihood of future AT	[142]
4	Cycling subjective experience	Systematic review of 50 studies	Developed a conceptual framework for emotional, sensory, and cognitive aspects of cycling experiences	Positive emotions (fun, relaxation, sociability) are associated with AT; researchers are urged to optimise for positive experiences	[81]
5	Stress causes in cycling	Delft, The Netherlands (n = 28), and Atlanta, USA (n = 41)	Explored cyclists' stated stress causes using quasi-naturalistic rides with surveys and interviews	TS from motor vehicles (83%), poor pavement (64%), and infrastructure deficiencies (58%) were the leading stressors	[143]
6	Barriers and enablers to cycling	Systematic review of 45 papers/reports	Identified perceived barriers and enablers to adults riding bikes for transport	Leading barriers were riding alongside motor vehicles and poor infrastructure; enablers were high-quality protected infrastructure	[145]
7	Perceived crash risks	The Netherlands, Belgium (Flanders, Brussels, Wallonia); cyclists over 40 years (Belgium)–55 years (Netherlands)	Compared perceptions of crash types causing hospitalisations among older/middle-aged cyclists	Most perceived bicycle–motor vehicle crashes as the greatest risk; underestimation of single-bicycle crash risk is also a barrier	[146]
8	Transport poverty and attitudes	Toronto, Canada (Rexdale neighbourhood, qualitative study)	Explored impacts of transport poverty on travel attitudes and behaviours using the Theory of Planned Behaviour, the Theory of Cognitive Dissonance, and the Habit Theory framework	Transport poverty limited behavioural control and reinforced car dependence; reduced consistent AT engagement	[153]

4.2.3. Policy and Planning Gaps

Policy frameworks in many cities continue to under-prioritise AT in planning and investment, resulting in insufficient dedicated bike lanes, safe crossings, and accessible

AT routes for YA [39,140,159]. Urban policies often favour motor-vehicle infrastructure, reinforcing a car-centric culture and deterring AT, even for short trips [73,75,160].

Targeted AT-promoting policies remain limited, with many cities lacking bike-sharing systems, pedestrian incentives, and urban design measures that explicitly improve walkability and cycling safety for YA [161–163]. Institutional support is inadequate, as many universities lack secure bike parking and municipalities neglect pedestrian infrastructure [74,164,165]. Strengthening AT participation in YA requires integrated networks, supportive governance, and coordinated cross-sectoral action [166] that prioritises active modes in both urban policy and budget allocation.

Policy and planning gaps create systemic barriers to AT among YA. Limited infrastructure investment, weak governance, and car-centric planning reduce walkability and cycling safety. In comparison, integrated and well-funded policies have shown measurable increases in AT uptake. Table 7 lists the key policy and planning gaps and their impact on AT in YA.

Table 7. Policy and planning gaps and their impact on AT in YA.

S. No.	Factors	Study Context	Study Focus	Impact on AT	Ref.
1	New transport infrastructure	Cambridge, UK; 469 adult commuters within 30 km of the new Busway	Quasi-experimental cohort analysis of the new busway and the traffic-free walking/cycling route	Sustainable transport infrastructure increased cycle commuting and active commuting among the least active adults	[159]
2	Local government cycling planning	Australia and New Zealand; national surveys of local governments	Surveyed urban/regional local governments on planning challenges for cycling	Strong policy support but weak implementation capacity at the local government level	[73]
3	Walking infrastructure governance	Kisii (Kenya) and Mzuzu (Malawi)	Examined barriers to implementing walking infrastructure in smaller urban centres	Decision-making challenges, limited provision of pedestrian infrastructure	[160]
4	Policy insights from social media	Turkey; >600,000 tweets (2016–2021)	Analysed barriers/drivers for cycling using topic modelling, sentiment analysis	Mixed barriers included safety, infrastructure, and economy; enablers included health, enjoyment, and socialisation	[161]
5	Policy-relevant AT research priorities	Australia; 259 reference group participants, 140 prioritisation respondents	Priority-setting exercise identifying top AT research and policy needs	Highlighted needs for road space reallocation, lower speeds, child-friendly policies, governance, and funding	[74]
6	Government AT promotion approaches	Victoria, Australia; scoping review of 996 policies in 123 documents	Analysed ‘hard’, ‘soft’, and governance measures in state/local AT policies	Multifaceted approaches identified, but low AT participation indicates gaps in impact	[166]
7	Effectiveness of new cycling infrastructure	Sydney, Australia; sub-regional city case study	Evaluated the design/implementation of new cycling infrastructure using Sustainable Mobility Theory	Poor design (steep gradients, unsafe widths, circuitous routes) limited usage despite investment	[165]

4.2.4. Young Adult Behaviours and Lifestyle

Young adulthood is a transitional life stage [53] marked by events such as starting university, entering the workforce, or relocating, all of which can reshape daily routines and transport choices [167–169]. BE quality, safety perceptions, and lifestyle demands shape AT decisions in YA [53,170]. Life events can disrupt or sustain AT. Academic and work pressures, relocation, and time scarcity often reduce AT participation, whereas prox-

imity to destinations and supportive campus and workplace cultures encourage it in YA [171–173]. Peer norms and a self-chosen commitment to AT strongly predict sustained participation [173].

AT engagement is embedded in broader lifestyle patterns, offering mental and physical health benefits [174,175]. However, time constraints and environmental barriers frequently undermine consistency in AT [176,177]. Effective interventions, therefore, need to combine infrastructure improvements with social support to encourage AT participation in YA [178,179]. The extant literature focused on AT among YA supports these claims. In a study of 7931 post-secondary students (mean age 22.3 years), distinct lifestyle clusters were identified. Among the total, 23% were active and neighbourhood-oriented, relying mainly on walking and cycling within local areas. In comparison, 11% were multimodal, combining active modes with transit and occasional car use, often making three or more trips per day [55].

These findings not only highlight the role of BE context but also reflect socioecological dynamics, where perceived safety, peer norms, and supportive community settings collectively influence YA active transport behaviour. YA behaviours and lifestyles mediate the influence of infrastructure and policy. Life transitions, time pressures, and competing responsibilities often reduce AT, while peer influence, supportive institutional cultures, and proximity to destinations foster healthier and more sustainable mobility choices in YA. Table 8 lists the YA behavioural and lifestyle factors and their impact on AT.

Table 8. Young adult behavioural and lifestyle factors and their impact on AT.

S. No.	Factors	Study Context	Study Focus	Impact on AT	Ref.
1	Transitional life stage and health	Broad review, YA across Europe/global	Examined life course transitions (education, work, family) and health implications	Life transitions create vulnerabilities that can disrupt healthy routines, including AT	[53]
2	Life events and travel behaviour	US university faculty, staff, and students	Analysed how life events and life stages affect changes in travel modality types	Relocation and family responsibilities increased car use, reducing AT	[169]
3	Habit discontinuity (moving house)	University students n = 250 (153 movers)	Tested whether moving house disrupted travel habits and altered mode choice	Relocation created “windows of opportunity” to form new AT habits	[172]
4	Peer effects in mode choice	University of Grenoble Alps, France; 334 employees	Investigated the influence of peer behaviour and social networks on AT	Strong peer effects encouraged AT	[173]
5	PA and mental health	427 university students, Turkey	Examined links between PA and mental health outcomes	Walking and moderate PA improved resilience and well-being	[175]
6	Environmental and psychosocial barriers	1349 Chilean university students	Identified barriers to AT and failure to meet PA recommendations	Time, effort, traffic, and planning demands discouraged AT	[177]
7	Student commuting patterns	686 students, University of Minho, Portugal	Analysed commuting modes and potential CO ₂ savings under modal shift scenarios	Proximity to campus created potential for AT; a large share of trips could shift from car to AT	[171]

4.2.5. Mixed and Overlapping Themes

Mixed and overlapping themes, presented in Table 9, highlight that AT among YA is shaped by the interacting environmental, social, and psychological factors. Supportive infrastructure alone is insufficient without parallel strategies addressing stress, cultural norms, and socioeconomic disparities.

BE quality and psychological stressors interact through interdependent mechanisms in shaping AT behaviour in YA [179,180]. High traffic density and inadequate pedestrian infrastructure constrain PA and heighten perceived safety risks and emotional discomfort, particularly among vulnerable users [181,182]. Infrastructure upgrades, such as protected bike lanes and pedestrian zones, are more effective in supporting sustained AT participation when complemented by supportive policies, including bike-sharing schemes and financial incentives [183,184].

In low-income areas, neglected BE infrastructure, poverty, and psychological stress collectively constrain AT participation in YA [185–187]. Taken together, the findings indicate that promoting AT in YA requires multilevel strategies that integrate BE features, mitigate TS, and incorporate socioecological influences.

Table 9. Mixed themes and their impact on AT.

S. No.	Themes	Study Context	Study Focus	Impact on AT	Ref.
1	Cycling mentorship programs	Canada; 197 residents (mostly newcomers)	Evaluated the impact of 12–16-week mentorship programs providing training, bikes, and equipment	Enabler—participants increased cycling for transport (to work/school/shopping) and reported higher confidence	[180]
2	Integrated behavioural strategies	Canada (synthesis of literature and a case study)	Combined psychological behaviour-change tools with the community-based cycling program evidence	Enabler—integrated psychological and program strategies accelerated cycling adoption	[179]
3	Street retrofit (Future Streets)	Māngere, New Zealand; controlled before-and-after study	Assessed effects of redesigned street hierarchy and AT infrastructure on speed/volume	Enabler—reduced speeds/volumes on local streets, creating safer conditions for walking/cycling	[181]
4	Socio-cultural influences on cycling	Auckland, New Zealand; survey and structural equation modelling	Investigated socio-cultural and demographic influences on bicycle use	Enabler—family, peers, and cultural factors strongly shaped cycling uptake	[183]
5	Youth perspectives on AT	Qualitative meta-synthesis of studies (ages 5–19)	Synthesised youth-reported barriers and facilitators of AT	Mixed—barriers included parental control, traffic, and weather; enablers included agency, supportive norms	[187]
6	Transportation disadvantage	Shenzhen, China; composite indicator analysis	Developed indicators to measure transport disadvantage by neighbourhood sociodemographic	Barrier—disadvantaged neighbourhoods had reduced accessibility and higher inequality in transport opportunities	[185]

4.3. Traffic Stress Patterns Based on Queensland 2023 Data

Most existing TS frameworks, including the widely used LTS, are based on static road design and average conditions [32,33]. While these frameworks capture physical infrastructure characteristics, they do not adequately account for temporal variability in traffic volumes and congestion, which substantially influence AT users' experiences. Morning, midday, and evening peaks routinely expose AT users to elevated stress caused by increased vehicle speeds, high vehicle volumes, and reduced infrastructure comfort. To address this limitation, this review draws on the 2023 traffic volume dataset from the Queensland Department of Transport and Main Roads (TMR), which reports average traffic volumes by hour and day of the week for state-controlled roads. This dataset reveals consistent temporal patterns that support a time-based extension to LTS classifications, enhancing their relevance for planning and design of AT infrastructure.

4.3.1. Weekday Traffic Patterns

The analysis of Queensland's 2023 traffic data [99] reveals distinct daily variations (Figure 6). Traffic volumes rise sharply from 6:00 a.m., with the first pronounced peak occurring between 6:00 and 9:00 a.m. (morning peak traffic stress, MPTS). This can be classified as very high stress (LTS 4). Traffic volumes dip slightly after 9:00 a.m. but remain elevated and relatively stable during 10:00 a.m.–2:00 p.m. (midday traffic stress, MDTS), corresponding to moderate-to-high stress (LTS 3–4). The highest peak is observed between 2:00 and 5:00 p.m. (evening peak traffic stress, EPTS), with maximum volumes around 3:00 and 4:00 p.m. This reflects very high stress (LTS 4) linked to school pickups and end-of-day commutes. After 5:00 p.m., traffic volumes decline steadily, reducing TS levels for AT users.

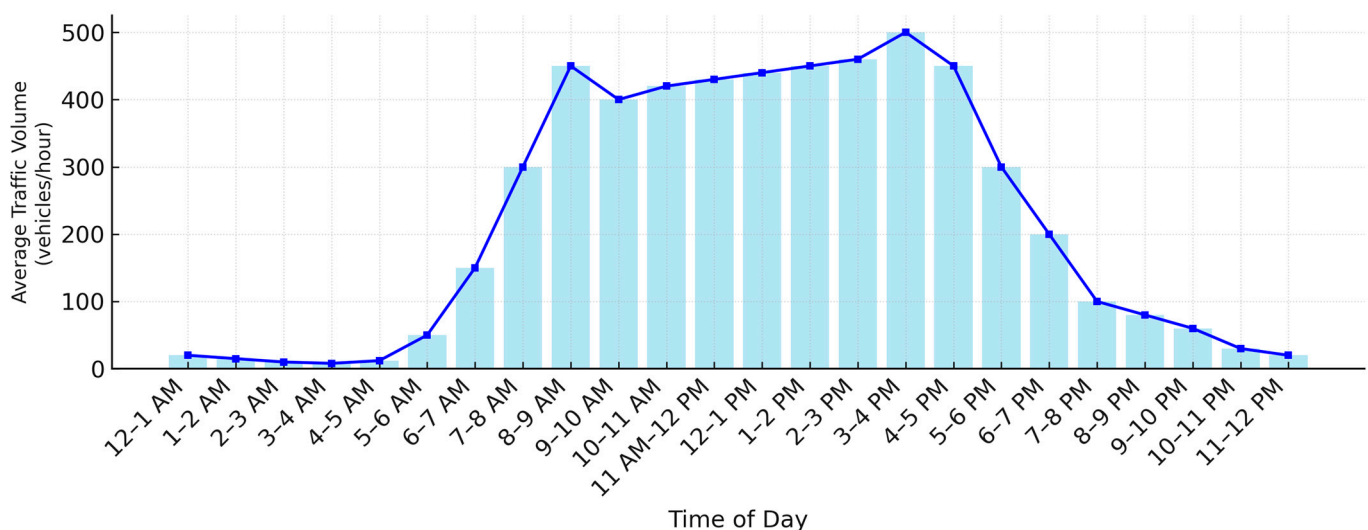


Figure 6. Temporal distribution of average weekday traffic volumes on Queensland state-controlled roads (2023) [99]. The x-axis represents the time of day (hour of the day), while the y-axis represents average traffic volume (vehicles per hour) (Diagram developed by the authors).

4.3.2. Weekly Distribution of Traffic

Average traffic volumes across the week (Figure 7) highlight clear contrasts between weekdays and weekend patterns. Volumes remain consistently high from Monday through Friday, reflecting commuting and school-related travel demand, with Friday showing the highest average. In contrast, weekend (Saturday and Sunday) volumes are markedly lower, with Sunday recording the lowest levels of the week. These patterns underscore the persistence of weekday commuting peaks and the shift towards more flexible, discretionary travel on weekends.

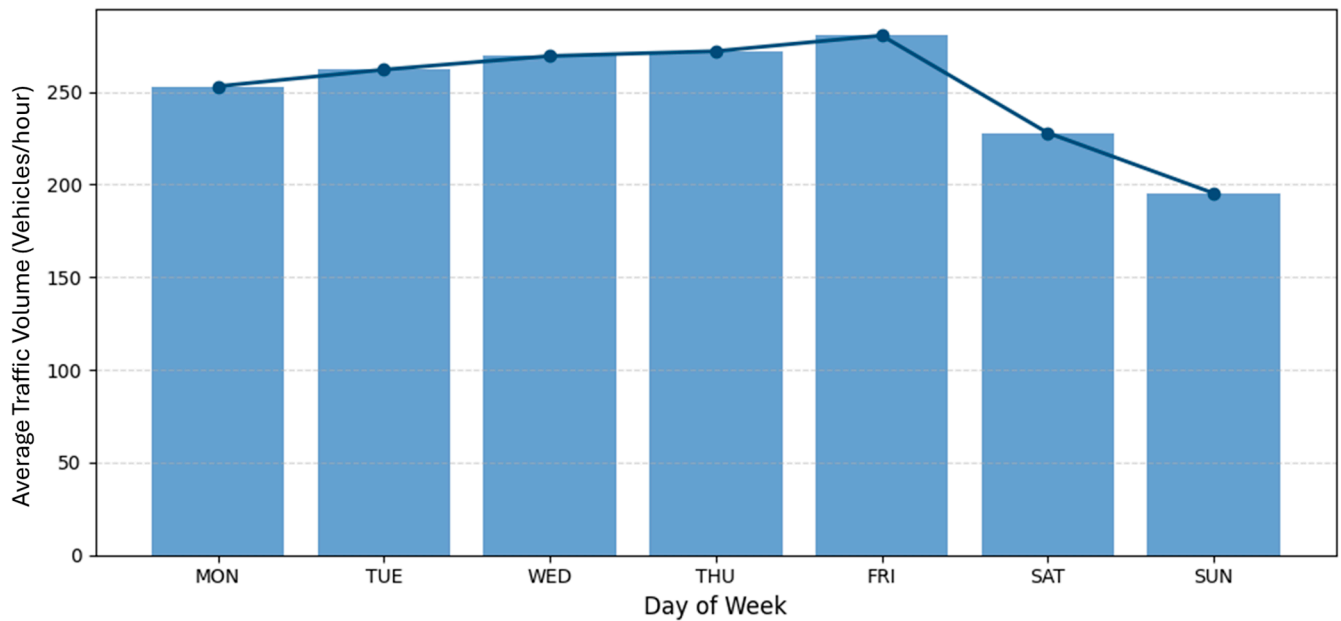


Figure 7. Average daily traffic volumes by day of the week on Queensland state-controlled roads (2023) [99]. The x-axis represents the day of the week, while the y-axis represents average traffic volume (vehicles per hour) (diagram developed by the authors).

4.3.3. Weekend Patterns

Weekend traffic patterns show a distinct profile compared with weekdays (Figure 8). Traffic volumes increase gradually from the early morning, peaking around 10:00–11:00 a.m. before declining through the afternoon and evening. Unlike weekdays, there are no sharp early morning peaks, and overall TS levels remain lower (LTS 2–3). Saturday volumes are consistently higher than those on Sunday, remaining elevated until early afternoon, while Sunday traffic drops earlier and more sharply, reflecting reduced urban mobility at the weekend (Figure 9). Recreational corridors may still experience moderate TS during the midday period, particularly on Saturdays.

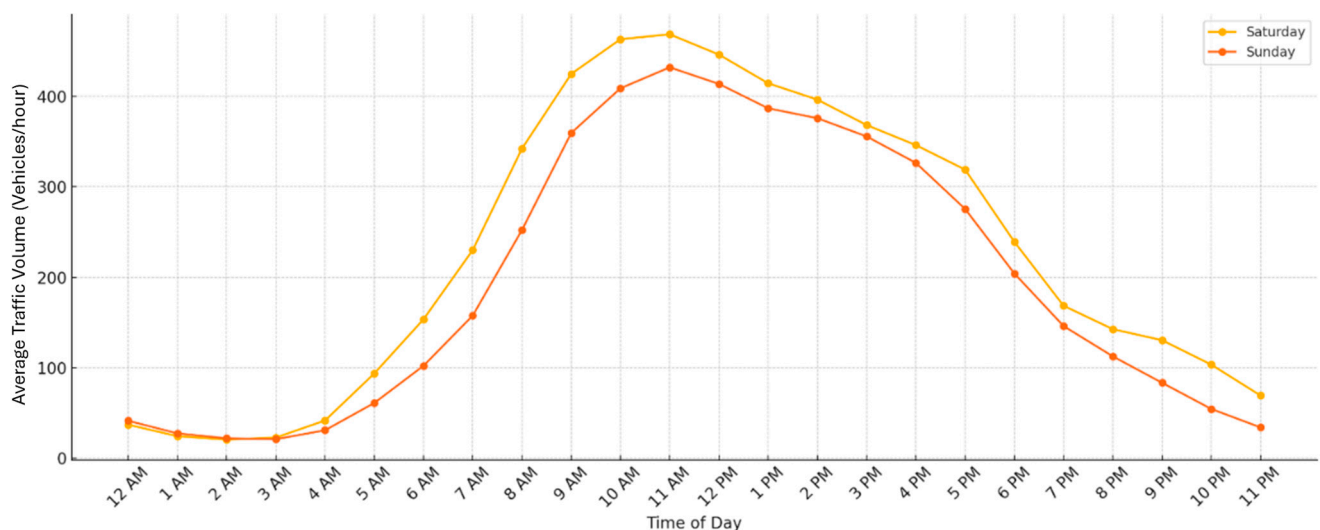


Figure 8. Average traffic volume per hour on the weekend [99]. The x-axis represents the time of day (hour of the day), while the y-axis represents average traffic volume (vehicles per hour) (diagram developed by the authors).

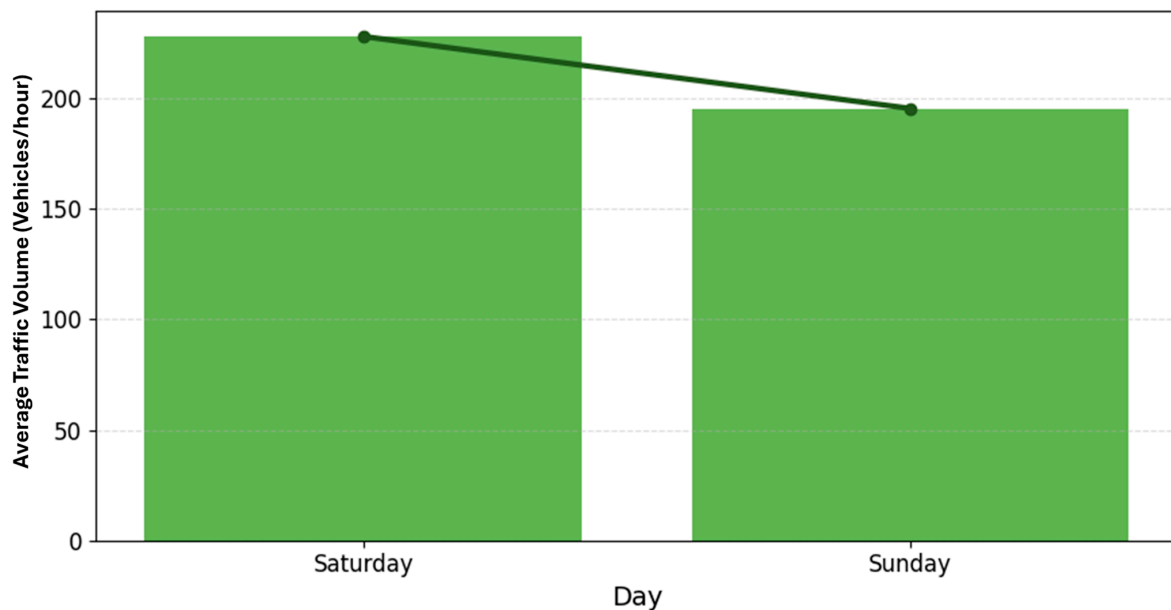


Figure 9. Average weekend traffic volumes on Queensland state-controlled roads (2023) [99]. The x-axis represents the day of the week, while the y-axis represents average traffic volume (vehicles per hour) (diagram developed by the authors).

4.3.4. Traffic Trends (2013–2023)

The median annual daily traffic (AADT) on Queensland state roads rose from approximately 2100 to more than 2500 vehicles per day between 2013 and 2023, as shown in Figure 10 [188]. This consistent increase, particularly in the post-pandemic period, indicates the continuing reliance on private vehicles. The lack of a substantial modal shift towards sustainable transport highlights limited progress in reducing car dependency. Rising AADT is projected to intensify congestion, emissions, and TS, reinforcing the need for integrated, time-responsive transport planning.

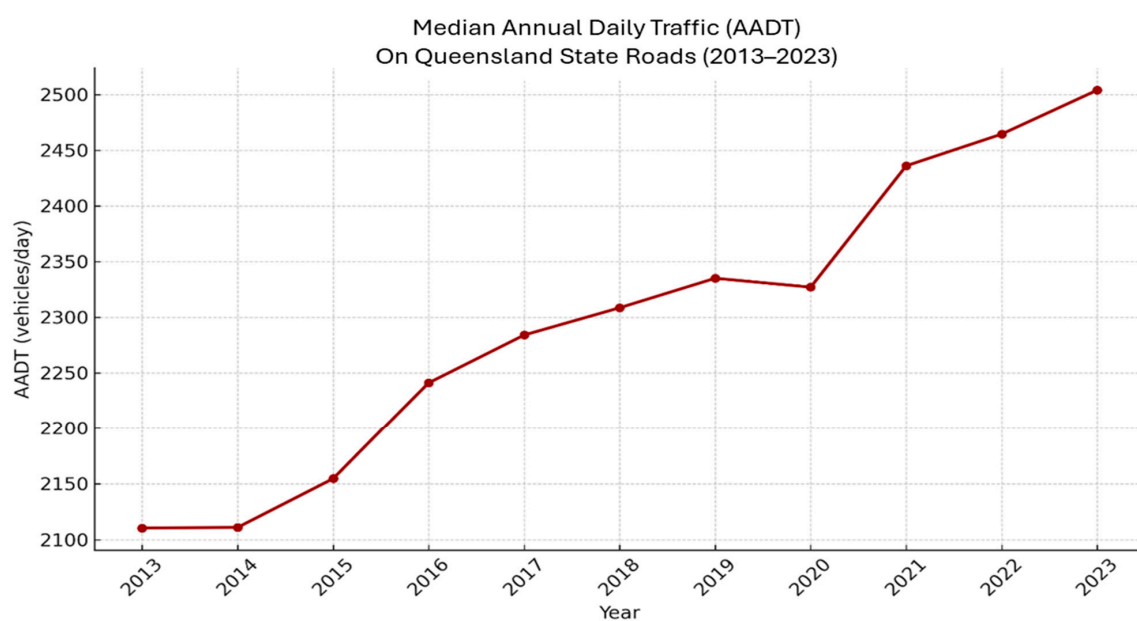


Figure 10. Median annual daily traffic (AADT) on Queensland state roads, 2013–2023 [188]. The x-axis represents years, while the y-axis represents median annual daily traffic (vehicles per day) (diagram developed by the authors).

4.3.5. Daily Traffic Stress Framework

The DTS framework advances beyond descriptive traffic counts by modelling how AT users experience stress throughout the day. It reframes congestion data into a conceptual tool that captures fluctuations in exposure to risk, safety, and comfort. This temporal extension of LTS moves the analysis from static classifications to a dynamic model that reflects realistic mobility conditions.

The framework assumes that AT users are more sensitive to congestion, speed, and crossing availability and that stress is cumulative, with physical risks amplified by psychosocial responses such as anxiety or avoidance. Peak periods are simplified into three broad bands to maintain generalisability, while recognising that local contexts may shift their exact timing. These assumptions allow heterogeneous traffic behaviour to be distilled into a model that is both interpretable and transferable.

Figure 11 visualises these dynamics across the daily cycle. The morning (MPTS) and evening (EPTS) panels illustrate environments of high stress, where dense traffic, narrow spaces, and proximity to vehicles subject cyclists and pedestrians into unsafe conditions. The midday (MDTS) panel, in contrast, shows lighter traffic volumes and more navigable space, signalling a temporary reduction in TS. This comparison demonstrates that TS is cyclical rather than constant, expanding or constraining AT opportunities depending on the time of day.

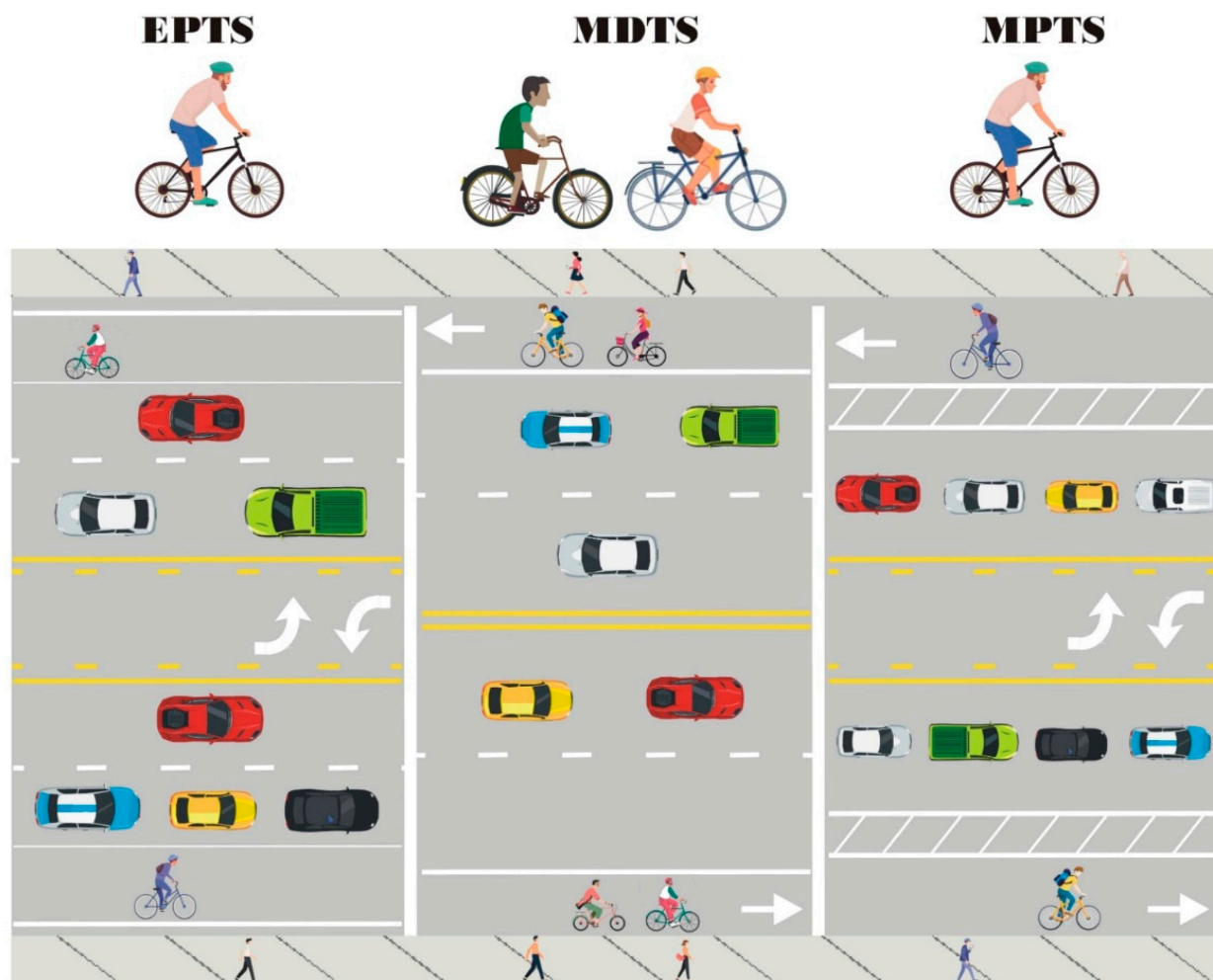


Figure 11. Conceptual illustration of DTS patterns across MPTS, MDTS, and EPTS. Arrows show direction of traffic movement (diagram developed by the authors).

The DTS framework provides a methodological step change by embedding temporal sensitivity into LTS. It enables practitioners to identify high-risk periods for AT users and to design interventions that respond to time-specific vulnerabilities. Infrastructure upgrades can be prioritised for morning and evening peaks, while midday windows may be leveraged for behavioural programs or workplace initiatives. Beyond practice, DTS enriches theoretical models of transport behaviour by linking TS exposure to temporal cycles, making it a transferable tool for urban planning, public health, and mobility research.

4.4. Developing the Stress-to-Step Ratio

The evidence base for SSR comprises peer-reviewed studies published from 2015 onward that quantify differences in daily step counts under varying BE, weather, and socioecological conditions. Chan et al. [106], Kondo et al. [189], and Dygryn et al. [105] were used solely to calibrate SSR, as they provide foundational step-count data under varying environmental conditions that are not available in more recent studies. Together, these studies establish the empirical basis for the analyses presented in Table 10.

Table 10. Studies reporting daily step differences.

Author	Country	Results
Hajna et al., 2015 [190]	Europe and Asia	A meta-analysis indicates that individuals in highly walkable areas logged 766 extra $\frac{\text{steps}}{\text{day}}$ compared to those in low-walkability areas (95% CrI: 250, 1271).
Hajna et al., 2016 [104]	Canada	The most walkable neighbourhoods were linked with 1345 additional $\frac{\text{steps}}{\text{day}}$ (95% CrI: 718, 1976). GIS-based walkability corresponded to walkable neighbourhoods, completing 606 more $\frac{\text{steps}}{\text{day}}$ (95% CrI: 8, 1203).
Dygryn et al., 2010 [105]	Czech Republic	Weekdays (high walkability = 12,035 steps vs. low walkability = 9916 steps); weekend days (high walkability = 9523 vs. low walkability = 7516 steps); whole week (high walkability = 11,318 steps vs. low walkability = 9230 steps)
Kondo et al., 2009 [189]	Japan	Participants in more walkable neighbourhoods accumulated $9364 \pm 567 \frac{\text{steps}}{\text{day}}$, while those in less walkable areas recorded $= 8293.5 \pm 490.7 \frac{\text{steps}}{\text{day}}$.
Hino et al., 2017 [191]	Japan	Step counts peaked at 19.4 to 20.7 °C. Below this range, each 1 °C increase corresponded to about 46.4 to 52.5 additional $\frac{\text{steps}}{\text{day}}$, whereas above the peak, each 1 °C increase corresponded to a decrease of about 98.0 to 187.9 $\frac{\text{steps}}{\text{day}}$.
Kim et al., 2022 [192]	Korea	A 1 °C increase in daily maximum temperature reduced the likelihood of walking practice: OR = 0.95 (95% CI: 0.94–0.97) in rural areas and 0.98 (95% CI: 0.97–1.00) in urban areas.
Chan et al., 2006 [106]	Canada	Weather affected activity: 14 mm of rainfall linked with 830 fewer steps (8.3% decrease), and a 20 kph higher wind reduced counts by 2–5%. Conversely, a 10 °C warmer day added +2.9% $\frac{\text{steps}}{\text{day}}$.
Klimek et al., 2022 [193]	Germany	Participants averaged 100.9 min of walking per day and 197.0 min of out-of-home time. Higher temperatures and sunlight increased walking, while humidity, wind, and rain reduced it.
Carlson et al., 2021 [194]	USA	Walking participation rose when weather was less often cited as a barrier: transportation increased from 23% to 40%, leisure from 42% to 67%. Weekly walking volume also increased (transport: 51 to 69 min, leisure: 64 to 98 min).
Ho et al., 2022 [107]	China	Optimal step counts recorded at 16–19.3 °C (city-specific). High temperatures above 30 °C reduced steps by 800–1500 per day, while temperatures below 5 °C also lowered counts.
Rodríguez-Gutiérrez et al., 2024 [195]	Spain	Step counts were highest at 14 °C and 13 h sunlight. Each +1 °C increase was linked with $+74 \pm 130 \frac{\text{steps}}{\text{day}}$, and each extra hour of the sun with $+315 \pm 237 \frac{\text{steps}}{\text{day}}$.

Application of the SSR framework quantifies how TS exposures translate into walking behaviour. We first present the evidence pool of studies reporting daily step differences (Table 10), followed by SSR calculations assuming daily exposure times of 30 min/day (Table 11). Table 10 shows that supportive BE consistently increases walking by 600–2000 $\frac{\text{steps}}{\text{day}}$, while environmental stressors such as heat, cold, rain, and wind reduce the step counts, particularly in extreme conditions. Socioecological characteristics, including mood, dog ownership, and vehicle access, produce additional variation. These values provide the inputs for calculating SSR.

Table 11. SSR calculations assuming daily exposure times of 30 min/day.

Author, Year	Exposure Type	Steps per Day/Results	SSR (30)
Hajna et al., 2015 [190]	BE (meta-analysis, walkability)	+766	+25.5
Hajna et al., 2016 [104]	BE (perceived walkability)	+1345	+44.8
Dygryn et al., 2010 [105]	BE (high vs. low, whole week)	+2088 (11,318 – 9230)	+69.6
Kondo et al., 2009 [189]	BE (walkability, high vs. low)	+1071 (9364 – 8293)	+35.7
Hino et al., 2017 [191]	Environmental (temperature above optimum, per °C)	−187.9 per °C	−6.3 per °C
Kim et al., 2022 [192]	Environmental (temperature vs. walking practice)	Each +1 °C reduced walking practice (OR 0.95 rural; 0.98 urban)	Not applicable
Chan et al., 2006 [106]	Environmental (rain 14 mm)	−830	−27.7
Klimek et al., 2022 [193]	Environmental (older adults, minutes/day)	100.9 $\frac{\text{min}}{\text{day}}$ walking; Normal to higher temperatures and more sunlight result in more walking; Greater humidity, wind, and rain result in less walking	Not applicable
Carlson et al., 2021 [194]	Environmental (weather barriers, NHIS survey)	Walking participation rose as weather was reported less often as a barrier—from 23% to 40% for transportation walking and 42% to 67% for leisure walking; Weekly walking time increased from 51 to 69 min (transportation) and 64 to 98 min (leisure).	Not applicable
Ho et al., 2022 [107]	Environmental (heat >30 °C vs. optimal)	−1500	−50.0
Rodríguez-Gutiérrez et al., 2024 [195]	Environmental (sunlight; per hour)	+315	+10.5 per h

Not applicable = studies that did not report daily step differences and reported odds ratios, minutes, or participation instead. These were retained in the evidence pool and described narratively but excluded from SSR calculations.

We applied the SSR formula using an assumed TSM value of 30 $\frac{\text{min}}{\text{day}}$, as previously listed in Equation (1), to all studies listed in Table 10. Step differences from each study were divided by these exposure times to yield SSR estimates in steps per stress-minute. The resulting values are presented in Table 11.

Application of the SSR framework revealed consistent patterns. Thirty minutes of daily exposure to supportive BE features increased walking by 20–70 steps per minute, equivalent to 600–2100 additional $\frac{\text{steps}}{\text{day}}$. In contrast, weather stressors produced negative SSR values, from −25 to −50 steps per minute of exposure under rainfall and hot days, equivalent to 750–1500 fewer $\frac{\text{steps}}{\text{day}}$. These findings demonstrate the feasibility of SSR as a novel step-based index that standardises how diverse stress exposures translate into walking behaviour.

5. Discussion

AT among YA is jointly shaped by BE features, exposure to TS, and the multi-layered determinants captured in SEM. AT-oriented urban design, supported by mixed land use and well-connected street networks, is consistently associated with higher levels of AT participation in YA [114,196]. Green spaces, shaded pedestrian routes and integration with public transport networks further promote AT in YA [197–200]. Perceived safety and self-efficacy influence modal choice, highlighting the interplay between BE and individual determinants [201–203]. A substantial proportion of existing research examines either BE or individual perceptions [204–206], with fewer studies assessing their combined effects. Positive norms and supportive infrastructure, such as secure bike parking, have been shown to increase AT participation in YA [207,208].

The association between BE and AT weakens once neighbourhood self-selection is accounted for [209,210], as mode choice is partly driven by individuals' preferences and interests. Individuals who prefer walking or cycling tend to reside in areas with supportive AT infrastructure [79,211], whereas those not interested in AT may remain inactive despite available facilities [212]. This underscores a key methodological limitation in the literature and highlights the importance of addressing additional contextual factors such as trip distance, time constraints, and adverse weather conditions, which significantly moderate AT participation in YA [213,214]. At the same time, perceived risk further complicates this relationship, as concerns about intersections, inadequate lighting, and limited surveillance often outweigh objective design features [215–217].

Findings across contexts remain mixed. For instance, Cerin et al. [39] reported robust associations between walkability, land-use mix, and AT across diverse international cohorts. Lamb et al. [218] showed that many such estimates may be biased and influenced by neighbourhood self-selection. This inconsistency highlights that the causal influence of BE on AT in YA cannot be disentangled without explicitly accounting for self-selection effects, which risks overestimating the benefits of urban design interventions and misguiding policy priorities.

TS has traditionally been described as the discomfort and perceived danger associated with challenging traffic conditions [29]. Beyond this, TS functions as a multidimensional barrier to AT in YA [33,219]. It manifests as both a physical and a psychological barrier [220–222], inducing fear and discomfort among AT users. Physical strain arises from muscular fatigue and discomfort caused by congestion, unsafe crossings, and poorly designed infrastructure, disproportionately affecting AT users such as cyclists and pedestrians [223]. Physiological responses include elevated heart rate and reduced heart rate variability due to exposure to pollutants and environmental stressors [224]. Real-driving measurement studies report higher emissions and fuel consumption under congested, stop-go conditions, implying that TS peaks often coincide with peak exposure for active travellers and nearby residents [225]. Emotional distress manifests as frustration, anxiety, or anger linked to congestion, aggressive driving, and traffic noise [226–228]. Framing TS in this multidimensional way underlines its cumulative impact, positioning it as a critical determinant of AT choice and participation.

The proposed DTS is a conceptual model with certain limitations. Its time intervals and stress thresholds are not universal but require calibration with local traffic and behavioural data to ensure contextual validity. Once calibrated, it offers a transferable framework for integrating temporal dynamics into AT planning worldwide. The complementary SSR provides a behavioural translation of TS exposure by expressing potential PA gains or losses as a function of TS exposure duration. When combined with local travel and step-count data, SSR enables comparative scenario testing, such as evaluating the behavioural effects of traffic calming, improved crossings, or low-stress corridors. The 30 min benchmark used in calculating SSR is a standardised reference, not a fixed assumption. It aligns with the WHO PA guidelines and provides a common behavioural denominator for cross-study comparability. Nonetheless, actual exposure to TS varies with BE configuration, trip purpose, and temporal conditions such as peak-hour congestion. Therefore, this baseline should be calibrated to context-specific exposure patterns while retaining a consistent methodological anchor to ensure validity and comparability across studies.

LTS captures the safety perceptions of transport networks, while DTS reveals when they become intolerable. By embedding temporal dynamics such as congestion peaks, trip timing, and TS exposure duration, DTS transforms TS from a static spatial score into a dynamic planning variable. It converts infrastructure design into time-responsive policy intelligence, enabling TS to be measured, predicted, and mitigated within the daily rhythm of urban mobility. This dynamic framing reconceptualises transport planning as both a spatial and temporal optimisation challenge, highlighting opportunities for time-sensitive policy interventions.

Conceptually, DTS extends LTS by reframing TS as a time-sensitive construct, capturing daily fluctuations that disproportionately shape YA mobility. SSR then standardises both LTS and DTS exposures into a behavioural metric, allowing comparability across contexts. Integrated with the 5Ds, which define spatial opportunity, and SEM, which embeds these dynamics within social and policy layers, the framework aligns environment, TS, and behaviour along a single pathway. This provides not only conceptual clarity but also an operational tool for planning, where interventions can be tested against temporal thresholds (DTS), behavioural equivalence (SSR), and the multi-layered supports captured in SEM.

Evidence of the influence of TS, BE features, and SEM on AT in YA extends beyond Australia. A study conducted in Japan indicates that BE effects on walking and cycling shift substantially when alternative modes are considered [229]. Safety concerns remain unaffected, while nearby services have strong and significant effects on both walking and cycling. Consistent with this, findings from Belgium show that safety and comfort are the strongest determinants of cycling environments [230]. Further, evidence indicates that reducing TS yields measurable gains in AT participation [231]. Longitudinal data from 14,011 block groups across 28 US cities over six years show that protected bicycle lanes are associated with participation rates 52.5% higher than standard lanes and 281.2% higher than shared-lane markings [232]. Well-connected, low-TS bicycle facilities significantly increase cycling activity [184,232] and overall AT participation. In the context of walking, perceived traffic safety mediates both the intention to walk and actual participation in walking [16].

Nevertheless, the evidence is not universally consistent. Some studies report weaker or inconsistent associations between TS and AT participation [148,233,234]. Shakeel and Rashidi [235] found that car-oriented attitudes negatively affect the likelihood of cycling, whereas bicycle-oriented attitudes positively influence cycling choices. Their hybrid choice model demonstrates that even with improvements in cycling infrastructure, strong car-oriented preferences can limit shifts towards cycling for non-work travel [235,236]. This

highlights a structural barrier often overlooked in infrastructure-led interventions, i.e., individual attitudes and cultural norms may override the availability of facilities. Consequently, infrastructure quality alone is insufficient to initiate or sustain AT behaviours [237], emphasising the need for socio-cultural interventions to complement physical changes. Psychosocial and cultural factors, including community attitudes, perceptions, and social norms, often have a stronger influence on AT participation in YA than physical changes [238].

The findings further underline the distinctiveness of YA in how they experience the interaction of BE, TS, and socioecological conditions. Unlike older adults, YA have flexible and irregular travel patterns that expose them disproportionately to peak-hour traffic stress, making temporal fluctuations in TS a decisive barrier. Unlike adolescents, their autonomy in travel choices is shaped less by parental oversight and more by confidence, social identity, and peer norms. These factors ultimately decide whether available opportunities and safety translate into actual transport choices. Taken together, these findings identify YA as a “tipping-point cohort” in global mobility transitions. Success in enabling their AT uptake could secure a generational shift toward sustainable AT, while neglecting it risks entrenching decades of car dependence. Addressing AT in YA is therefore not only a research priority but a generational imperative.

By integrating BE, SEM, and TS or LTS, this review demonstrates that AT in YA depends on a three-stage interaction pathway. The BE features generate spatial opportunity, perceived TS determines whether this opportunity is experienced as safe, and socioecological supports decide whether safety is translated into behaviour. Failure at any stage collapses this chain, clarifying why infrastructure investments alone often fail to achieve sustained behavioural change in terms of AT in YA. This failure chain shows that neglecting the conversion of opportunity into safety, or safety into behaviour, is the most common reason for the underperformance of large urban AT projects. Therefore, a multilevel strategy linking urban design, traffic calming, and supportive policy offers the most reliable route to large-scale AT adoption. Key priorities should include fostering mixed-use hubs around campuses and workplaces, implementing peer-led programmes, and limiting car dominance to secure long-term behavioural change for AT in YA.

6. Conclusions

This review highlights three key findings. First, supportive BE with higher density, connectivity, and land-use mix consistently enables AT. Second, TS and high-LTS conditions act as persistent barriers, undermining perceived safety and discouraging participation. Third, socioecological factors, including self-efficacy, peer influence, and social support, mediate these effects by helping YA to translate opportunity into actual behaviour.

Integrating the 5Ds of BE, TS, LTS, and SEM provides a clear pathway for promoting AT among YA. Dense, well-connected, mixed-use settings with nearby destinations create opportunity, while de-stressed networks achieved through protected lanes, safe crossings, and low-speed streets enhance perceived safety. Socioecological factors, particularly psychosocial supports such as confidence-building, peer influence, and behavioural incentives like bike-sharing schemes, translate perceived safety into sustained participation. A multilevel strategy linking urban design, traffic calming, and supportive policy therefore offers the most reliable route to large-scale AT adoption. Key priorities include fostering mixed-use hubs around campuses and workplaces, implementing peer-led programmes, and limiting car dominance to secure long-term behavioural change.

Methodologically, this review advances interdisciplinary research at the intersection of urban planning, transport studies, and public health. The proposed DTS framework adds temporal sensitivity to LTS classifications, while SSR translates diverse stress exposures into a common step-based outcome. DTS and SSR establish a new agenda for operationalising

transport–health research into planning practice, providing a framework for interventions that are spatially equitable, temporally sensitive, and socially embedded. These findings align with the United Nations Sustainable Development Goals (UNSDGs) 3, 11, and 13, positioning AT as both a public health imperative and a climate solution.

This study has several limitations. First, due to limited YA-specific data, studies involving adolescents and broader groups were included. TS and BE features are broadly relevant across various age ranges, although this may constrain age-specific interpretation. Second, developmental differences and inconsistent classifications of YA further complicate the attribution of effects to this age group. Distinguishing these effects was not always possible, given the small number of YA-focused studies, although many behavioural patterns appear transferable across adjacent cohorts. Third, search terms such as TS and AT often retrieved irrelevant occupational, psychological, or physiological studies, complicating scope alignment. In addition, the review was restricted to three repositories and to articles published in the last decade, which may limit coverage. Variations in study design and measurement approaches may also influence the consistency and comparability of the findings. A similar study conducted with different or expanded keywords may yield different results.

Building on this review, the proposed DTS and SSR frameworks should be empirically tested across diverse urban contexts to strengthen their generalisability and policy relevance. Such validation would advance their application in planning and public health, while positioning them as practical tools for mitigating TS and promoting AT among YA.

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Abbreviations

The following abbreviations are used in this manuscript:

AT	Active Transport
BE	Built Environment
DTS	Daily Traffic Stress
LTS	Level of Traffic Stress
PA	Physical Activity
SDGs	Sustainable Development Goals

SEM	Socioecological Model
SSR	Stress-to-Step Ratio
TS	Traffic Stress
TSM	Traffic Stress Minutes
WHO	World Health Organization
YA	Young Adults

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